Wheat yield and grain quality as affected by tillage, sowing time and nitrogen fertilization under rainfed Mediterranean conditions

G. Amato, D. Giambalvo, L. Stringi, G. Di Miceli and A.S. Frenda
Dipartimento di Agronomia, Coltivazioni erbacee e Pedologia - Università di Palermo,
Viale delle Scienze, 90128 Palermo, Italy

SUMMARY – The research was carried out in 9 sites (5 in 1999-00 and 4 in 2000-01) of a inner area of Sicily different for soil type, slope, exposure and preceding crop. The following treatments were studied: (i) conventional tillage and sowing at conventional time (CT); (ii) no tillage and sowing at conventional time (NTc); and (iii) no tillage and early sowing (NTe). In 2000-01 the effects of three nitrogen fertilization treatments (single application at planting, P, and split dressing at two different rates, S and S+) were also evaluated. No tillage systems (NTc and NTe) significantly increased grain yield compared to CT treatment; no differences were observed between the two sowing dates. The productive benefits of no tillage were associated with a decrease of grain protein content that was heavier with early sowing. Regarding N fertilization treatments, S compared with P allowed a significant yield increase; no interaction with tillage technique was found. At the lowest fertilizer rate, split fertilization allowed a significant increase of grain protein content only in NTe.

Key words: Wheat, no tillage, sowing time, N fertilization.

RÉSUMÉ – *"Rendement du blé et qualité du grain par rapport au labour, l'époque de semis et la fertilisation azotée en conditions pluviales méditerranéennes". La recherche a été réalisée dans 9 localités (5 en 1999-00 et 4 en 2000-01) dans un territoire interne de la Sicile distinct d'après le type de sol, pente, exposition et précédent cultural. Les traitements étaient : (i) labours et semis ordinaires en époque ordinaire (CT) ; (ii) sans labours et semis en époque ordinaire (NTc) ; et (iii) sans labours et semis anticipé (NTe). En 2000-01 les effets de trois traitements de fertilisation azotée (P : application simple au semis ; S et S+ : fractionnée avec deux doses différentes) ont été également évalués. Les systèmes sans labour (NTc et NTe) ont augmenté de manière significative le rendement en grain comparé à CT ; il n'a été observé aucune différence entre les deux dates de semis. Les avantages productifs sans labour ont été associés à la réduction du contenu protéique du grain qui était plus marquée avec le semis anticipé. En ce qui concerne les traitements de fertilisation azotée, le traitement S vs P a montré une augmentation significative de rendement ; aucune interaction avec la technique de travail du sol n'a été trouvée. Avec la plus faible dose d'engrais, la fertilisation fractionnée a permis une augmentation significative de la teneur en protéines dans le grain uniquement sur NTe.*

Mots-clés : *Blé, sans labour, époque de semis, fertilisation azotée.*

Introduction

No tillage compared with conventional tillage systems may offer many benefits including reduction of soil erosion risk, improvement of soil biological and bio-chemical properties and reduction of energy inputs even if sometimes the technique can imply negative aspects such as greater problems in weed control, soil temperature reduction and increase of soil compacting.

Concerning grain production, the response of no tillage is variable depending on cropping and environmental conditions. Bonari *et al*. (1994) and Giambalvo *et al*. (1999) indicated that no tillage is most effective in self-structuring soils and particularly in dry years; therefore the technique appears suitable for the Mediterranean environment often characterised by water deficiencies during the cropping season. However, tillage being just a component of a crop system, to fully exploit the potentiality of the no tillage technique it is necessary to develop "no-till systems" suitable for different environments. Therefore the system approach seeks management solutions to valorise the advantages and to solve the problems associated with tillage change.

The present research aimed to evaluate, in different sites of a semi-arid Mediterranean environment, the applicability of the no tillage technique compared to conventional tillage in interaction with other components of wheat crop management; in particular, considering that no tillage can allow earlier sowing than the conventional tillage system, an early sowing time was included to evaluate the effect of a longer growing season on grain yield and quality; furthermore the research evaluated the response of two varieties different for cycle length and, only in one of the two years of the trial, also the effect of the nitrogen fertilisation technique (timing and rate).

Material and methods

The research was carried out in an inner area of Sicily (S. Stefano Q., AG) at the experimental farm "Pietranera". Within the farm (about 700 ha large) 5 sites in 1999-00 and 4 sites in 2000-01 were chosen for different altitude and slope, soil characteristics and preceding crop (Table 1). In each site, the following treatments were studied: (i) CT, conventional tillage and sowing at conventional time; (ii) NTc, no tillage and sowing at conventional time; and (iii) NTe, no tillage and early sowing. Two varieties were used: (i) Simeto, a very common cv in Mediterranean areas characterized by earliness, high productivity and good grain quality; and (ii) Zenit, a later cv with very good grain quality. The CT treatment included mouldboard ploughing (30-35 cm) and harrowing cultivation (10-15 cm) to prepare a proper seed bed. In no-till treatments, weeds were controlled with Glyphosate (0.6 l a.i./ha before sowing); the plots of NTe were not sprayed in 1999 as weeds were absent at sowing time. Sowings at early and conventional time were done, respectively, on 10 November and 12 December in 1999 and on 2 November and 14 December in 2000. In 1999-00 nitrogen fertilizer was applied using the conventional technique for the cropping area: single dressing at planting at the rates of 73 or 99 kg N/ha depending on previous crop (faba bean or wheat, respectively).

Table 1. Some characteristics of the trial sites

	Sites								
	1	2	3	4	5	6	7	8	9
Altitude (m a.s.l.)	422	352	175	220	163	246	373	406	170
Slope (%)	15	5	5	10	0	10	5	10	0
Exposure	S	S-W	S-E	N-E	–	N-E	S-W	N-W	–
Preceding crop	Wheat	Faba b.	Faba b.	Wheat	Wheat	Wheat	Faba b.	Wheat	Faba b.
Clay (%)	47.2	55.1	56.5	52.2	23.5	61.0	50.1	47.9	28.4
Sand (%)	31.9	18.9	20.6	28.3	60.4	19.0	22.4	30.2	50.5
pH (in water)	7.8	7.9	8.1	8.0	7.9	8.0	8.2	7.9	8.1
Organic matter (%)	2.0	2.5	1.8	1.7	1.8	2.3	1.7	1.3	1.1
CEC (meq/g)	15.8	39.5	28.1	23.9	26.5	37.5	36.8	18.7	26.4

In 2000-01 trials, the following nitrogen fertilization techniques were also studied: (i) P, single application at planting (as for 1999-00 trials); (ii) S, split dressings at planting (50%) and at 4^{th}-5^{th} leaf stage (50%); and (iii) S+, split dressings as "S" but increasing the rate of nitrogen fertilizer of 20%. For P and S the fertilizer rate was the same as for 1999-00 trials.

In 1999-00 the treatments were laid out in a split-plot design with three replications and with the sowing system as main plot and variety as sub-plots. In 1999-00 a split-split-plot design was used with three replications and with sowing system in the main plots, variety in the sub-plot and N fertilisation in the sub-sub plots. In both years the sub-plot area was 150 m^2.

Every year, all plots were also supplied with P fertilizer (69 kg P_2O_5/ha); weeds were controlled chemically (Triasulfuron 7.4 g/ha + Clodinafop-propargyl 0.055 l/ha + Cloquintocet-mexyl 0.014 l/ha). Grain yield, yield components and straw were measured at maturity by manually harvesting 4 sampling areas of 4 m^2 within the sub-plot at the first year and within the sub-sub-plot at the second year. Ash, nitrogen and gluten grain content were determined using a Bran & Luebbe InfraAlyzer 450; gluten index was measured according to Perten (1990).

A statistical analysis was performed with the data of the plot with single N fertilizer application at planting in all 9 sites using a split-plot design according to Gomez and Gomez (1984). Data of each site were analysed separately and, if homogeneity of variance was detected, combined over sites with site as a random variable. Significant treatment means were separated by LSD at the 5% level. For the 4 sites where the N fertilization technique was also studied, the statistical analysis was performed using a split-split-plot design and the same procedures as above.

The two cropping seasons were different according to the rainfall (373 and 599 mm respectively in Sept.-June 1999-00 and 2000-01). In 1999-00 rainfall was poor in Sept.-Oct. (42 mm) and well distributed throughout the winter and spring; in 2000-01 winter rainfall accounted for more than 70% of the total annual rainfall and spring was particularly dry (65 mm).

Results and discussion

The grain yield of the 9 "environments" (sites) of trial ranged between 2.89 and 5.33 t/ha. On average, adopting the conventional sowing time, no tillage compared with conventional tillage allowed a significant grain yield increase (Table 2). The response was positive at all sites; however, in 5 cases (sites 1, 4, 7, 8 and 9) no significant differences were observed. At site 3, a 70% grain yield increase was recorded; the production of CT was particularly poor due to a very low ear fertility (19.1 and 28.6 kernels per ear respectively for CT and NTc; $P \leq 0.01$) and number of ears/m^2 (228 and 277 respectively; $P \leq 0.05$).

Table 2. Grain yield (t/ha) as affected by tillage technique and genotypes in the different sites

	Sites									Mean
	1	2	3	4	5	6	7	8	9	
CT	2.48	4.38	1.91	2.97	2.95	3.10	3.56	3.27	5.26	3.31
NTc	2.95	5.22	3.26	3.43	3.60	3.76	3.65	3.76	5.52	3.92
NTe	3.23	5.45	3.67	3.25	3.65	2.22	4.35	3.84	5.20	3.86
LSD ($P \leq 0.05$)				0.642						0.214
Simeto	3.27	5.51	3.24	3.42	3.76	3.14	4.43	4.09	5.90	4.07
Zenit	2.50	4.52	2.66	3.01	3.04	2.91	3.27	3.16	4.76	3.32
LSD ($P \leq 0.05$)					0.379					0.126
Site mean	2.89	5.02	2.95	3.21	3.40	3.03	3.85	3.63	5.33	3.69

No consistent effect was found of early sowing (NTc vs NTe) on grain yield; the positive effects found on individual sites were counteracted by negative effects on other occasions. In particular, at site 6 a significant yield decrease (-40.9% compared to NTc; $P \leq 0.01$) was recorded due to a strong weed presence occurring during the early growth stages; weed competition drastically reduced the plant density and, as a consequence, the number of ears/m^2 (110 and 267, respectively for NTe and NTc; $P \leq 0.01$). At site 7, the significant benefits of NTe compared with NTc (+19.2%; $P \leq 0.05$) was the result of a moderate improvement of all the yield components.

Both varieties had a similar response to tillage system (interaction not significant). Simeto was always more productive than Zenit (on average 4.11 vs 3.36 t/ha) even if the differences between the two varieties varied among the environments (decreases of Zenit ranging from -7.2 to -26.1% of the Simeto production).

With the conventional sowing time, the productive benefits of no tillage compared to conventional tillage seemed mainly due to a higher density of ears/m^2 and to a higher seed weight (Table 3).

Between the two no tillage treatments, a greater amount of straw was obtained with the early sowing indicating that the longer growth period determined effect only on the vegetative activity.

Table 3. Mean effect of tillage treatments on plant height, straw, yield components and some grain quality parameters

	Plant height (cm)	Straw (t DM/ ha)	Ear/m^2	Kernel/ ear	1000-kernel weight (g)	Test weight (kg/hl)	Protein content (%)	Ash content (%)	Gluten content (%)	Gluten index
CT	74.4	5.82	250	30.5	44.1	81.4	15.6	1.95	14.4	67.8
NTc	78.0	6.38	278	31.5	45.2	82.1	14.6	1.85	13.4	68.7
NTe	83.7	6.78	242	35.5	46.9	82.2	13.5	1.77	11.7	78.8
LSD ($P \leq 0.05$)	1.10	0.365	11.8	1.51	0.83	0.33	0.36	0.034	0.54	5.29

The grain quality parameters were strongly influenced by tillage treatment. When the sowings were done at conventional time, the protein and gluten contents were significantly higher with conventional tillage; this result, observed at all sites (interaction tillage x site not significant), is mainly related to grain yield increase (dilution effect). It is interesting to point out that the protein and gluten contents decreased further in the early sowing probably because, in such conditions, there had been a greater autumn leaching of nitrogen fertilizer (applied in a single dressing at planting).

N fertilization technique significantly affected grain yield with similar effects for each tillage treatment (interaction between the two factors not significant) (Table 4). On average, split dressing allowed a significant increase of about 5% compared to single dressing at planting. Although the interaction between fertilization technique and "environments" was significant, in two (8 and 9) of the four sites no differences among the treatments were detected. The 20% extra N fertilizer did not determine significant yield variations.

Table 4. Grain yield and protein content as affected by tillage and nitrogen fertilization techniques

	Grain yield (t/ha)				Grain protein content (%)			
	P	S	S+	Mean	P	S	S+	Mean
CT	3.80	3.96	3.94	3.90	14.89	14.77	15.41	15.03
NTc	4.17	4.41	4.55	4.38	14.56	14.49	14.91	14.65
NTe	3.90	4.15	4.07	4.04	13.68	14.24	14.62	14.18
LSD ($P \leq 0.05$)		NS†		0.315		0.372		0.356
Mean	3.96	4.17	4.19		14.38	14.50	14.98	
LSD ($P \leq 0.05$)		0.187				0.401		

†NS: not significant.

Adopting conventional sowing time, no consistent benefits were found of splitting the nitrogen application on grain protein content; on the contrary a positive effect was observed in NTe (Table 4). For all tillage treatments, grain protein content increased significantly up to the highest N rate used.

Conclusion

The results obtained indicate that no tillage is a viable strategy for Mediterranean environments such as those of the inner area of Sicily. In fact, in all of the trial conditions, no tillage, compared to conventional tillage, allowed highest grain yield; the benefits, however, varied markedly among the different environments. On average the early sowing did not allow consistent yield increase; in comparison with no tillage and sowing at conventional time, fluctuating variations were recorded and decreases were mainly associated with greater problems in the control of early weed growth.

On the whole, the two varieties tested in the trials showed similar responses to the different crop management techniques; in particular the later genotype did not show any benefit for the longer

growing season of the early sowing. Furthermore, the results showed, on the whole, a worsening of grain quality with no tillage; with early sowing, splitting nitrogen fertilization may contribute to reduce this negative effect.

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